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THE HORSE-RADISH FLEA-BEETLE: ITS LIFE HISTORY AND DISTRIBUTION.

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CONTENTS.

	Page.		Page.
Introductory	1	Recent injury	12
Descriptive	3	Natural enemies	13
Distribution in North America	5	Associated insects	13
Origin and dissemination	6	Methods of control	13
Review of literature	7	Summary	14
Food plants	8	Bibliography	15
Seasonal history	8		

INTRODUCTORY.

Nearly every year there is brought to this country some insect immigrant, and frequently, in the course of time, these immigrants prove to be pests. As a rule, they are introduced through the large seaports, particularly Boston, New York, New Orleans, and San Francisco, from which points they spread westward, northward, or southward, and less frequently eastward. Occasionally such an insect is carried by commerce beyond the coasts and makes its first appearance inland. This happened in the case of the insect to which the senior author has given the name of the horse-radish flea-beetle (fig. 1) and which is known zoologically as *Phyllotreta armoraciae*

NOTE.—Horse-radish is widely cultivated in the United States and especially where the horse-radish flea-beetle is now most injurious. The farm value of horse-radish is not far from $400,000 per annum, considering its growth for home use. Two other insects than the horse-radish flea-beetle are especially attracted to it, the horse-radish webworm (*Plutella armoracia* Busck) and the horse-radish caterpillar (*Evergestis straminalis* Hübn.). Neither of these is of any importance, but in the southern range of growth of horse-radish the harlequin cabbage bug is a most destructive pest, seeming to prefer this plant to other crucifers. The horse-radish flea-beetle will continue to spread and soon become a dangerous pest unless growers practice methods of control.

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Koch.[1] It was obtained for the first time in 1893 on the withered leaves of horse-radish in a vacant lot within a fourth of a mile of the grounds of the Columbian Exposition at Chicago, Ill. It is possible that the species was actually introduced at about that time, but probably the time was one, two, or more years earlier, and it was not reported as a pest until 1908.

The larvæ as well as beetles live on the leaves and petioles of the common horse-radish ([*Nasturtium*] *Radicula armoracia*) and when numerous injure the plant to such an extent as to reduce materially the root crop. The larvæ mine the petioles or midribs (fig. 2), while the adults feed on the leaves, causing the characteristic flea-beetle injury—withering and dying—or gouge deep pits in the petioles or midribs.

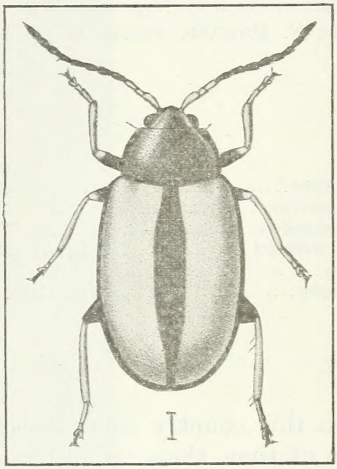

FIG. 1.—The horse-radish flea-beetle (*Phyllotreta armoraciae*): Adult. Greatly enlarged. (Original.)

This beetle belongs to the same genus as the well-known injurious striped cabbage flea-beetle (*Phyllotreta vittata* Fab.) but may be distinguished readily from all other species occurring in this country by its elytra or wing-covers, which are mostly of a pale cream color with a comparatively narrow sutural black stripe, as shown in figure 1.

The horse-radish flea-beetle, having recently become an economic factor in the growing of horse-radish[2] on a commercial scale in Brown County, near Green Bay, Wis., the junior author has been able to trace its life economy and history. It first appeared in sufficient numbers to be seriously injurious in the summer of 1914, when it was reported and observed by Prof. J. G. Sanders. In the two years following, the beetles reappeared in large numbers in the same locality.

While as yet not very generally distributed and confined to attacks on the relatively unimportant crop of horse-radish, the possibility that this insect in its new domain may adapt itself to the other and more important members of the cultivated cruciferous plants renders it worthy of such notice as can be supplied.

[1] Order Coleoptera, family Chrysomelidae, subfamily Halticini.

[2] The authors desire to acknowledge the cooperation of the Department of Economic Entomology, University of Wisconsin, and the many favors received from Mr. George B. Smith, Green Bay, Wis., on whose farm the junior author was stationed when many of the data in this paper were obtained.

DESCRIPTIVE.

THE ADULT.

In appearance *Phyllotreta armoraciae* is distinct from any species of flea-beetle belonging to or introduced into this country. It is somewhat larger and wider than any of the native species of the genus. It is of oval form, strongly convex, and black in color. The first three antennal joints, the apices or tips of the four anterior femora, the tibiæ, and the tarsi are reddish yellow. The elytra are very light yellowish, or cream color, nearly white, with a very thin black lateral margin and a broadened sutural stripe, widest at the middle and constricted at each end and extending from the base of the thorax to the apex of the elytra, where it joins the lateral line. The frons or front is very finely, and the prothorax and elytra densely, punctate. A sensitive pore from which proceeds a seta is located on the lateral margin, which is behind the anterior angle. In the male the fourth antennal joint is slightly thickened and longer than the fifth. In the female the fourth and fifth joints are equal.

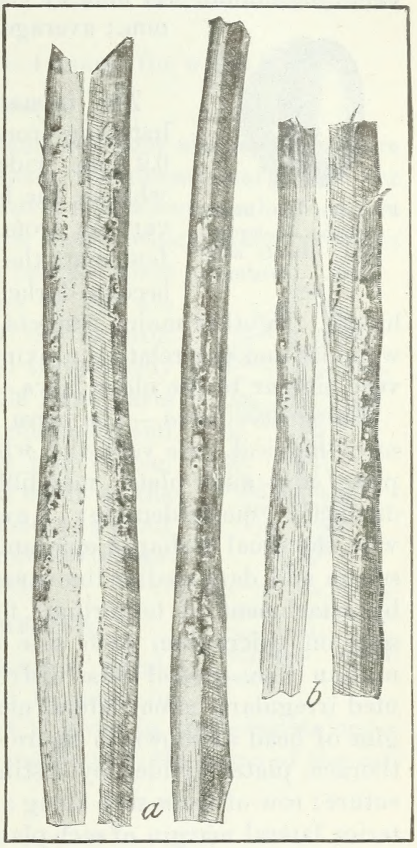

FIG. 2.—Work of the horse-radish flea-beetle in leaf petioles of horse-radish. (Original.)

The average length is from 3 to 3.3 mm., but individuals have been observed where there is a variation of from 2.6 mm. to 3.4 mm. and a variation in width of 1.3 mm. to 1.9 mm.

The following synonymy is recognized:

Phyllotreta armoraciae (Koch).

Haltica armoraciae Koch, Entom. Hefte, v. 2, p. 75, 1803.

Haltica vittata Steph., Mandibulata, p. 292, 1831.

The species is also treated systematically by Illiger, Duftschmidt, Gyllhenhal, Schilling, Redtenbacher, Seidlitz, Foudras, Allard, Leesberg, and others.

THE EGG.

The egg (fig. 3) is oval, capsule-like, deep orange in color, with no special characteristic marking or reticulations visible under a 4-millimeter objective. The following are the measurements taken from 22 eggs: Maximum, 0.47 mm. by 0.84 mm.; minimum, 0.26 mm. by 0.43 mm.; average, 0.33 mm. by 0.57 mm.

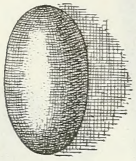

FIG. 3.—The horse-radish flea-beetle: Egg. Highly magnified. (Original.)

THE LARVA.

The immature larva.—The larva, just after hatching from the egg, is about 1.3 mm. long by 0.2 mm. wide; the color of the entire body is whitish, the head, thoracic plates, and anal plate varying from whitish to pale brown. Within a few hours the head, thoracic plate, and anal plate become darker, and a day or more later turn deep brown. In other major respects, excepting the numerous transverse wrinkles and the relative proximity of the setæ, the young larva is very similar to the older larva.

The mature larva.—The larva (fig. 4), when full grown, is slender subcylindrical, pale yellowish white, with dark brown head, thoracic plate, and anal plate; mandibles distinctly quadridentate; head with the usual V-shaped epicranial suture and dark median line caused by attachment of tentorium; five setæ on epicranium each side of median line, several setæ distributed irregularly about lateral margins of head as shown in figure 4; thoracic plates divided by distinct suture; row of three setæ along anterior lateral margin of each plate; one on lateral posterior angle; four minute setæ on posterior inner margin of each plate; one seta on inner anterior angle; mesothorax with pale chitinous plates bearing setæ, two in anterior row, four in posterior row, four on slightly elevated pleural area; metathorax similar. The thoracic legs each bear one claw.

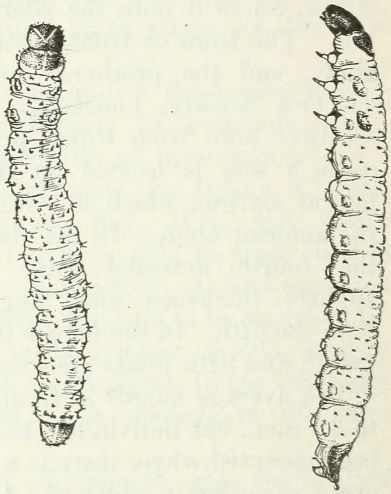

FIG. 4.—The horse-radish flea-beetle: Larva; at left, dorsal view; at right, lateral view. Tubercles and tuberculiferous hairs more prominent than in nature to show arrangement. (Enlarged.) (Original.)

The abdominal segments bear dorsally three rows of slightly elevated chitinous plates, each of which gives rise (when not continuous) to a seta; the first row comprises six, the middle row two, the

third row four; at the ends of the third row, a little anterior, are the slightly elevated chitinous pleural plates, bearing three setæ each.

The anal plate approximates a rectangle in outline with the sides converging toward the posterior end and corners rounded. The whole surface except the chitinous plates is covered with minute granulations.

The length just prior to pupation is 4.8 mm., the width 0.8 mm.

THE PUPA.

The pupa (fig. 5) is white and about the same size as the mature beetle. The antennæ are placed along the dorsal margin of the wings and extend around on the ventral side about one-half way to the middle of the body. Between the wings, which extend down to the fourth abdominal segment, is a narrow space in which the tarsi of the three pairs of legs are placed. The femora and tibiæ of the anterior pairs of legs are parallel and extend transversely across the body over the wings, while these parts of the posterior pair of legs extend obliquely and are under the wings, the tips being just visible. Two forceps-like chitinous processes occur at the apex or tip of the last abdominal segment; a stout seta on the tip of each femur, and a number of setæ at various points on the head and body.

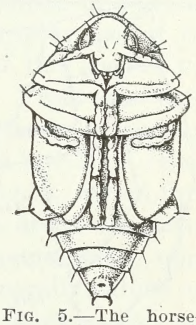

FIG. 5.—The horse-radish flea-beetle: Pupa, ventral view. Enlarged. (Original.)

DISTRIBUTION IN NORTH AMERICA.

The following is a list of localities in which the horse-radish flea-beetle is known to occur in North America. (Fig. 6.) This list is given in approximate order of the first noted appearance of the insect, with the name of the collector in each case:

Chicago, Ill., 1893 (Chittenden).
Guttenberg, Iowa, 1894 (Hugo Soltau).
Okauchee, Wis., 1896 (Dr. E. G. Love).
Dane County, Wis., 1900 (Dr. Wm. S. Marshall).
Bloomington, McLean County, Ill., 1900 (Wolcott).
Glencoe, Ill., 1908 (J. E. Fehd).
Milwaukee County, Wis., 1908 (Dr. S. Graenicher).
Whitewater, Wis., 1909 (Univ. Wis. Coll.).
Westmount, Quebec, 1910 (A. F. Winn).
Lake County, Ind., 1910 (Wolcott), (Blatchley).
Shermerville, Ill., 1912 (Retzinger).
Chester, N. J., 1913 (H. O. Marsh).
Green Bay, Wis., 1914 (J. G. Sanders), 1915 (N. F. Howard).
Highland Park, Mich., 1915 (L .Miller).
Omaha, Nebr., 1915 (Ehlers).
Potsdam, N. Y., 1915 (Chas. Dury).
Ashtabula County, Ohio, 1915 (Robt. Sim).
Madison, Wis., 1916 (N. F. Howard).

ORIGIN AND DISSEMINATION.

The horse-radish flea-beetle is of European origin, and was first described by Koch in 1803[1] from Germany. It is a well-known species in the Old World, and its specific name is derived from its favorite food plant (*Vasturtium*) *Radicula armoracia*. Like all of the striped flea-beetles of the true genus Phyllotreta, the present species breeds on cruciferous plants.

As to the means of introduction of this species in the heart of this country, it was probably brought in with horse-radish and less probably in marsh cress (*Radicula palustris*), or possibly with some potted plant. It is not impossible that these plants were brought to America expressly on account of, if not actually for, exhibition at

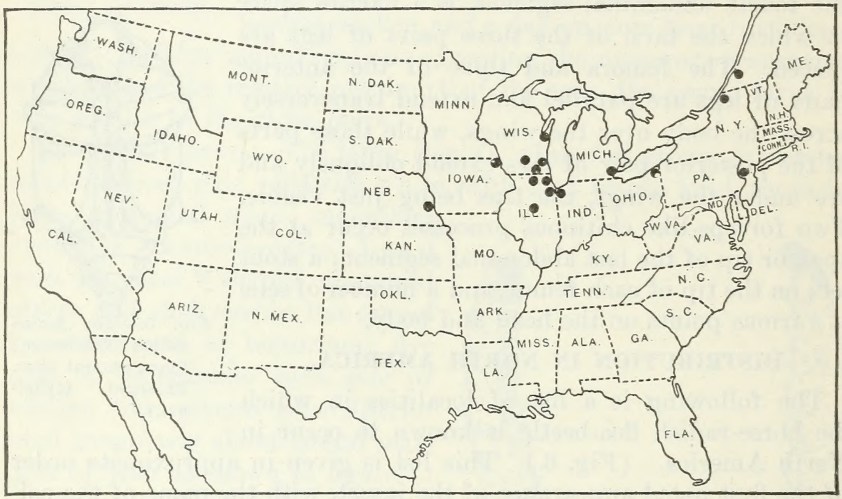

FIG. 6.—Map showing present known distribution of the horse-radish flea-beetle. (Original.)

the Columbian Exposition. It is remarkable, however, in being introduced, not near a seaport, but so far inland.

In the place of its nativity this species ranges throughout middle Europe. Among early records of its establishment in the United States are Guttenberg, Iowa; Chicago and Bloomington, Ill.; and Okauchee, Wis., about 30 miles due west of Milwaukee, and in 1896 there was a strong probability that it would soon spread to Missouri and perhaps to southern Minnesota and Michigan—in other words, that it would establish itself in the course of time in the upper Austral and, perhaps, a portion of the Transition region in the vicinity of its known range at that time. This would include Nebraska in the West and Ohio in the East. The natural progress of most insects introduced from Europe is westward, but there are several

[1] Numbers in parentheses refer to "Bibliography," p. 15.

examples, notably the Colorado potato beetle, of an insect pest which has first traveled eastward.

The predictions made in 1896 that the horse-radish flea-beetle probably would spread soon to southern Minnesota and Michigan were practically correct, as the species is known to be near the State line of Minnesota in Iowa. It had reached Michigan by 1915 and had spread to Ohio and Nebraska the same year. That it would take an eastward sweep as far as Potsdam, N. Y., Quebec, Canada, and northern New Jersey was scarcely expected for years to come. It is now near the border line of Pennsylvania and will undoubtedly spread to that State and to southern New York. The tendency is northward rather than southward, Bloomington, Ill., being the most southerly locality from which it has been reported.

Until otherwise known (and there is little likelihood of learning anything more definite with regard to the first appearance of the horse-radish flea-beetle), it must be concluded that this species was introduced first into Illinois in or around Chicago. From this center it has spread westward and northward, and has evidently taken large commercial jumps eastward, or has been introduced into New Jersey independently, but has made little progress to the south. From present knowledge it apparently prefers the regions about the Great Lakes, but in time doubtless it will be quite as numerous in other waterways and tributaries, even in moist places generally, which are the natural habitat of its principal food plants—horse-radish and marsh cress. In the course of time the somewhat scant records doubtless will be greatly enlarged, showing thereby a more general distribution than is known at present. It has been remarked that in Wisconsin, in the Green Bay region, conditions for the development of this species are highly favorable. This is in the northern portion of the Transition Life Zone, while Quebec is in the Canadian portion of the Boreal Zone.

REVIEW OF LITERATURE.

An account of the horse-radish flea-beetle was given by the senior author in 1895, which is now out of print (3).[1] In this article mention was made of the first occurrence of the species in this country and of the European literature, and the insect was compared with other species of its genus. The original technical description was published in 1803 (1). In 1893 Julius Weise (2) gave a systematic and detailed description of the species with biologic notes and bibliography. In 1897 (4) the senior author noted the occurrence of this insect in Wisconsin in 1896 and suggested the probable range

[1] Figures in parentheses refer to Bibliography, p. 15.

of the species. In 1900 A. B. Wolcott (5) made mention of the capture of the beetle at Bloomington, Ill. Injury by this species was briefly mentioned by J. J. Davis in Illinois in 1910 (6). In 1910 also, Blatchley (7) recorded its occurrence in Lake County, Ind., and in 1911 A. F. Winn (8) observed it at Westmount, Quebec, Canada, on horse-radish received from Montreal. It is not stated, however, whether the insect was believed to come from Montreal or from Westmount. In Europe brief notes were published by Heikertinger in 1911 and 1912 (9, 10).

FOOD PLANTS.

This beetle is partial to horse-radish and marsh cress. It was taken once on young cabbage in hotbeds in early spring by the junior author but was not observed to be eating. The future no doubt will reveal the possibility at least of other host plants.

SEASONAL HISTORY.

THE EGG.

The eggs are deposited from the latter part of April or early May through spring and summer until early August. The manner of placing and the position are variable, but the preferred location is on the tender petioles of young leaves, in the crevices where they leave the root. A few eggs have been found on the ground and on different places on the leaves, above and below the ground, and also carefully placed in the pits made in the stems and petioles by the larvæ or adults. They usually occur in small masses, either carefully arranged side by side in single rows, or two rows high, or carelessly piled without order. Occasionally an egg is found standing on end. The attachment to the plant is not very secure and often an egg-mass falls on the slightest disturbance. In the cages from 2 to 26 eggs were laid at intervals by a single female. While the most frequent number of eggs deposited was 22, at times 44 were deposited, indicating that about 22 eggs are developed in the ovarian tubes at one time. Copulation often takes place between deposition of batches of eggs, but it has not been determined whether or not this is necessary before the deposition of each batch. Judging from analogy, however, it may not be necessary. Hundreds of eggs were obtained in the insectary, but the egg record of one gravid female (Table 1) will suffice to show the egg-laying capabilities of the species. This female was placed in a vial with a portion of horse-radish leaf May 1, 1915, and the total number of eggs laid was 418.

TABLE 1.—*Egg record of a single female horse-radish flea-beetle.*[1]

Date.	Number of eggs deposited.	Remarks.
May 17	22	
27	22	
28	17	
June 3	23	Within 48 hours.
7	26	
8	2	
14	4	
17	.....	Male added.
21	25	
22	.....	Copulating.
25	44	Within 48 hours.
27	24	
29	44	Within 48 hours.
30	.....	Copulating.
July 1	28	Hatched July 12.
2	21	
3	22	
12	39	Within 72 hours.
14	.....	Mass; not counted; estimated at 22.
17	.....	Copulating; eggs laid about July 11 hatched.
18	.....	Copulating.
22	7	Copulating; within 36 hours.
30	26	Within 5 days.
Aug. 3	22	Within 72 hours.
7	.....	Female dead; male still alive.

[1] Within 24 hours in each case, unless otherwise mentioned, eggs were always removed.

Incubation.—The incubation period of the egg varied from 7 to 14 days, as the following data show:

TABLE 2.—*Incubation period of eggs of horse-radish flea-beetle.*

Number deposited.	When deposited.	Date of hatching.	Incubation period.	Larvæ working.
			Days.	
20	May 1	Before May 17	14 (approximate)	May 17.
(.)	do	May 11	10	
39	May 11	May 25	14	
28	July 1	July 12	11	
	July 10, 11, 12	July 17	7 (approximate)	
13	June 27	July 4 or 5	8 (approximate)	

. The months of May, June, July, and August were from 3.6° to 5° F. below normal.

THE LARVA.

On hatching the young larva crawls about the leaf for some time. Several individuals, observed over an hour, showed no particular course. Some went up toward the tip, others toward the crown, where they were lost from sight, but none started feeding. A small, tender petiole, recently invested by numerous larvæ, showed that they had entered at different places along the inner side.

As the larvæ grow and feed in the tissues of the petioles and midribs of the leaves, their presence is indicated by darkened or dead areas, where they have approached the surface. When the larvæ are

very numerous, the petiole is tunneled to the extent that it shrinks considerably and causes the leaf to wither and die at the tip and about the margins. When the larva is ready for pupation, it leaves the petiole and enters the ground. The exit holes, which soon collapse and appear as brown spots, are also characteristic of larval injury.

When both larvæ and adults occur together, the former are the more injurious. The injury which the adults cause to the young shoots early in spring as they are breaking through the soil is possibly more serious than subsequent injuries.

That the larva may live in the roots of the plant has been clearly demonstrated since it was first reported to the senior author. A potted plant died and was left intact for about a month. When the pot was wanted for another experiment the soil was found to contain several larvæ and pupæ. Only the shell of a root remained, the contents having been completely devoured by the larvæ. The pupæ transformed to normal adults shortly afterward. This habit of descending to the roots is not very general, however, for it has never been observed while roots peeled for the shredder were being examined.

After leaving the plant the larva enters the soil to a depth of from one-eighth to one-fourth of an inch or even 3 inches. Here it remains for 4 or 5 days, when it becomes white and short and thick. In this form it is inactive. From 2 to 6 days, usually 3 or 4, intervene before pupation.

The total larval period of an individual which was deposited as an egg on May 1, and which was hatched about May 15, was 48 days (about May 15 to about July 6). Another required 52 days; two others required about 57 days, two others 64 days, and two others 66 days.

The two larvæ which developed in 48 and 52 days, respectively, each remained 10 days in the pupal stage. Three other individuals also passed the pupal stage in 10 days, but one required 12 days, while three required from 12 to 13 days.

On September 11, 1915, a few pupæ in the cages had not yet transformed. April 17, 1915, the adults were already numerous about the ground where the shoots of horse-radish were just appearing, or about to appear.

This flea-beetle, like others of its kind, and like most leaf-beetles, hibernates in the adult stage. Careful search for pupæ from time to time practically proves this.

In Wisconsin only one generation appears annually.

The total period of time from egg laying to adult ranges from 77 days to about 90 days in the cases where complete records were obtained. Repeated attempts to obtain eggs from the adults of the current season failed.

The length of the egg-laying period, as shown by the record of an individual given above, is about 75 days, from the middle of May to the first of August. It is certain that this beetle emerged in 1914, probably in August or the first of September, and it is fair to assume that the species would have lived longer in nature had it not been killed by predators, parasites, disease, or the like. This shows the species to be exceptionally long-lived, living about a year in the adult stage.

The fact that the males are as long lived as the females may possibly be due to the fact that copulation is necessary at intervals during the egg-laying period.

RECORD OF EXPERIMENTS IN 1916 AT GREEN BAY AND MADISON, WIS.

April 24, a pair of beetles confined with horse-radish plants.
April 30 to May 5, copulation observed.
May 11, 15 eggs deposited within 24 hours or less.
May 12, 12 eggs in fold of leaf; might have been overlooked the day before.
May 17, 31 eggs found deposited since May 12.
May 22, 24 eggs found over Sunday, about 48 hours.
May 24, 20 eggs and copulation observed.
May 25, 25 eggs observed.
May 29, 48 eggs obtained over Sunday in about 48 hours.
May 31, moved to Madison, Wis.
June 4, 66 eggs obtained since May 30; copulation observed.
June 9, 44 eggs, approximately, observed since June 4.
June 14, 60 eggs found in 24 hours.
June 15, 49 eggs seen in about 24 hours.
June 21, 27 eggs obtained since June 15.
June 24, 44 eggs seen in 24 hours.
June 27, 48 eggs deposited within 24 hours or less. At this point the observations were discontinued.

HATCHING RECORD.

The same difficulty which was experienced in 1915 in the hatching of the eggs was observed this year. Of the entire number of eggs obtained from the female whose record is given above, a total of 513, the following hatched:

June 4, 1 egg deposited May 17 hatched, 17 days.
June 9, 1 egg deposited May 17 hatched, 22 days.
June 14, 7 eggs deposited June 9 hatched, 7 days.

As noted in the table of the 1916 records (Table 3), some of the larvæ died and only a few of these cases are mentioned: the remainder, being unimportant to the records, are not recorded. All dates on which observations were made are given.

TABLE 3.—*Life-history record of the horse-radish flea-beetle during 1916.*

Date eggs laid.	Date larva leaves plant.	Egg and larval stages.	Date of pupation.	Prepupal period.	Date of emergence.	Total pupal period.	Egg to adult.
		Days.		*Days.*		*Days.*	*Days.*
	July 20	52	July 20	.....	Died	.....	.....
	21	53	27	6	.....	.....	.....
	21	53	27	6	July 31	10	63
	24	56	27	3	31	7	63
	24	56	28	4	.....	.....	.....
	.....	.....	24	.....	Died	.....	.....
	July 27	59	31	4	Aug. 5	9	68
	27	59	31	4	7	11	70
	27	59	31	4	7	11	70
	27	59	31	4	2	7	66
	27	59	31	4	Died	.....	.....
	27	59	31	4	Died	.....	.....
	.....	.....	27	.....	July 31[1]	.....	63
	.....	.....	27	.....	31[1]	.....	63
	.....	.....	31	.....	Aug. 5	.....	68
	Aug. 28	60	Aug. 2	5	5	8	68
	28	60	2	5	Died	.....	.....
	28	60	3?	6	Died	.....	.....
	31	63	.....	.....	Aug. 5	6	68
	31	63	5	5	13	13	75
	31	63	5	5	13	13	75
	31	63	5	5	13	13	75
	31	63	5	5	13	13	75
	Aug. 2	65	7	5	Died	.....	.....
May 29[1]	2	65	9	7	Died	.....	.....
	2	65	Died	.....	.....	.....	.....
	2	65	Died	.....	.....	.....	.....
	5	68	Aug. 7	2	Died	.....	.....
	5	68	9	4	Died	.....	.....
	5	68	Died	.....	.....	.....	.....
	5	68	Died	.....	.....	.....	.....
	5	68	Died	.....	.....	.....	.....
	5	68	Died	.....	.....	.....	.....
	.....	.....	Aug. 5	.....	Died	.....	.....
	Aug. 7	70	13	6	Died	.....	.....
	7	70	Died	.....	.....	.....	.....
	9	72	Died	.....	.....	.....	.....
	9	72	Died	.....	.....	.....	.....
	9	72	Died	.....	.....	.....	.....
	9	72	Died	.....	.....	.....	.....
	.....	.....	.....	.....	Aug. 7	.....	70
	Aug. 13	75	Aug. 20	7	Died	.....	.....
	13	75	20	7	Died	.....	.....
	13	75	20	7	Died	.....	.....
	.....	.....	13	.....	Aug. 20	.....	83
	.....	.....	13	.....	Died	.....	.....
	.....	.....	.....	.....	Aug. 20	.....	83
	.....	.....	.....	.....	20	.....	83
	.....	.....	20	.....	25?	.....	88[1]

[1] Approximate.

SUMMARY OF TABLE.

Average combined egg and larval stages	days..	61.4
Average prepupal period, 30 individuals	do....	4.9
Average total pupal period, 12 individuals	do....	10
Average egg to adult, 20 individuals	do....	71.8

OTHER RECORDS.

Appearance record: First observed on leaves of horse-radish just breaking through the ground at Green Bay, Wis., April 20, 1916.
Copulation first observed May 2.

RECENT INJURY.

An account of recent injury by the horse-radish flea-beetle was received from a correspondent at Shermerville, Ill., who wrote January 3, 1917, substantially as follows, and who, later, furnished specimens:

I should like your advice on an insect which destroys my horse-radish. It is causing thousands of dollars loss every year in this community, and there seems

to be no way to destroy it. It is very small, yellow with black stripes, and it hops; inside of the leaves there are about 25 or 50, according to the size of the leaf. They do their damage when the horse-radish first sprouts after planting, eating off the sprouts as they come up. We have for years hauled out all old dead leaves, after marketing the horse-radish, and burned them. Paris green kills the leaves; kerosene solution does not kill the bug. Every year I plant about 35,000 plants, and the last two years only about 8,000 developed; besides the loss, I have less and less plants each year. There are several planters who have lost their entire crop on account of this insect.

NATURAL ENEMIES.

No parasite or disease of any sort has been observed in the field or in confinement. This is undoubtedly an oversight, since other flea-beetles have natural enemies, such as parasites of the adults, and in time these will probably come under observation. From Glencoe, Ill., a larva apparently predacious on the larva of this species was received.

ASSOCIATED INSECTS.

Associated with this species at Madison, Wis., were three species of minute maggots, (*Elachiptera*) *Crassiseta nigriceps* Loew, *Oscinis pallipes* Loew, and *Agromyza scutellata* var. *variegata* Meig. The first was found in horse-radish stems with the flea-beetle, and adults were reared from larvæ boring in the same stems, often in the same tunnels, as the flea-beetle larva. The third species was reared in horse-radish flea-beetle rearing cages with the preceding. This and probably one or more related species have often been reared from horse-radish stems both at Green Bay, Wis., and Madison, Wis., but just what part they play in the economy of this beetle is unknown. The adults frequently annoy the beetles by flying around and apparently attempting to alight on them.

METHODS OF CONTROL.

SPRAYING.

The injurious flea-beetles of the group to which this species belongs have never been satisfactorily treated by means of insecticides, to the knowledge of the authors. The same applies to other groups of small flea-beetles which attack solanaceous plants, like potato and egg-plant. The powerful hind legs which enable these insects to jump like fleas assist them in escaping from plants during spraying operations, and it is a matter of general knowledge among practical entomologists that it can not be very well determined how much poison, if any, they obtain by feeding on the poisoned surface of leaves. Many experiments have been made, and in practically every case the results have been negative. On the other hand, where Bor-

deaux mixture has been applied, the flea-beetles of different groups are nearly always repelled. It is evident that arsenicals repel, but in the case of flea-beetles Bordeaux mixture is more effective, a fact which has been known for many years.

During the season of 1914, when injuries by the horse-radish flea-beetle in Wisconsin were very serious and the root crop was much reduced, it was found necessary to bring roots from farther south to supply the usual trade. At this time arsenate-of-lead paste, 6½ pounds to 50 gallons of water, was used four times with considerable success. In the spring of 1915 the field was plowed, the roots collected, stripped of every vestige of leaves, and planted about a quarter of a mile from the old bed. This reduced the beetles to such an extent that very little injury was apparent until the middle of June, 1915.

On June 23 the plants were sprayed with arsenate of lead, and the numbers were reduced considerably. About three weeks later the poison was applied again. In the latitudes of Wisconsin, Michigan, Ohio, Pennsylvania, Delaware, New York, Indiana, and Iowa the spray should be administered at intervals from about the last week in April until late in July.

VALUE OF CULTURAL PRACTICES.

The importance of the employment of methods for the control of these insects as pests is exemplified by the experience of a firm at Green Bay, Wis. Before the advent of flea-beetles, truckers were able to raise horse-radish on a large scale from the same beds for several years at a time, but now the abundance and destructiveness of this flea-beetle makes it necessary to change these cultural practices completely in order to produce a crop, and it is necessary to replant a new bed from old roots every season.

SUMMARY.

The growing of horse-radish in the North is menaced by the introduction from Europe of a small insect known as the horse-radish flea-beetle. The beetle is oval in outline, about one-eighth of an inch long, with yellow elytra or wing-covers bordered with black, and with a longitudinal black band through the middle. The larvæ or young bore into the petioles or midribs of horse-radish, and the adults feed on the leaves and gouge deeply into the midribs, causing drying and death.

The beetle was first recognized in this country at Chicago, Ill., in 1893, since which time its area of distribution has increased until it now occurs from New York and New Jersey to Quebec, Canada, and westward to Nebraska.

The species passes the winter in hibernation as a beetle, coming forth in its northern range in April and May.

While as yet destructive only to horse-radish, its capabilities of becoming a pernicious pest, should it adapt itself to the economically more important cruciferous crops, must be acknowledged, and measures should be taken for its suppression wherever possible.

No systematic control program has been adopted as yet. Bordeaux mixture, a powerful repellent against flea-beetles, applied on the first appearance of the insect will prevent much injury, and if arsenate of lead is used later it should hold the insect in check.

When a new bed is to be planted a location should be chosen as far removed as possible from any infested bed. It is advisable also to destroy all volunteer plants, not only to keep the insect in check but in some cases to suppress it as a weed.

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